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Inose et al.

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(54) **VANE PUMP**

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**

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F04C 15/06	(2006.01)
F01C 1/067	(2006.01)
F01C 21/18	(2006.01)
F02M 59/12	(2006.01)
F01C 21/10	(2006.01)
F04C 2/344	(2006.01)

(52) **U.S. Cl.**

CPC ***F02M 59/12*** (2013.01); ***F01C 21/108*** (2013.01); ***F04C 2/3446*** (2013.01); ***F04C 15/06*** (2013.01)

(58) **Field of Classification Search**

CPC F04C 15/06; F04C 2/12
USPC 418/133, 268, 82
See application file for complete search history.

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(57) **ABSTRACT**

A vane pump includes: a rotor that is coupled with a rotation shaft to rotate; a plurality of vanes that are slidably held by a plurality of vane grooves which are disposed in a radiation direction in an outer circumferential portion of the rotor; a cam ring that is arranged to surround the rotor and the plurality of vanes; and a side plate that covers the cam ring and includes a supply unit which supplies a working fluid into the cam ring between the cam ring, an outer circumference of the side plate being recessed to a radially inner side of the rotation shaft to form the supply unit, in which an outer circumference of the supply unit and an inner circumference of the cam ring are shaped along each other.

9 Claims, 11 Drawing Sheets

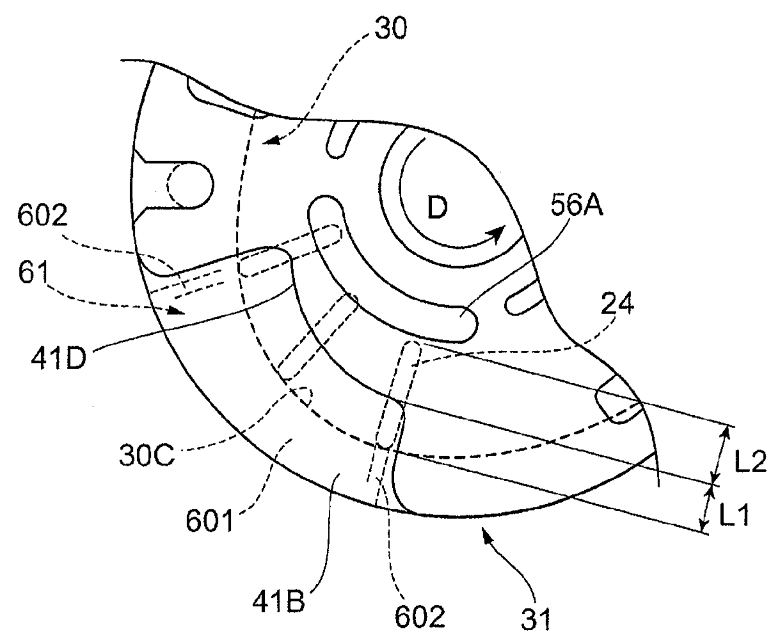


FIG. 1

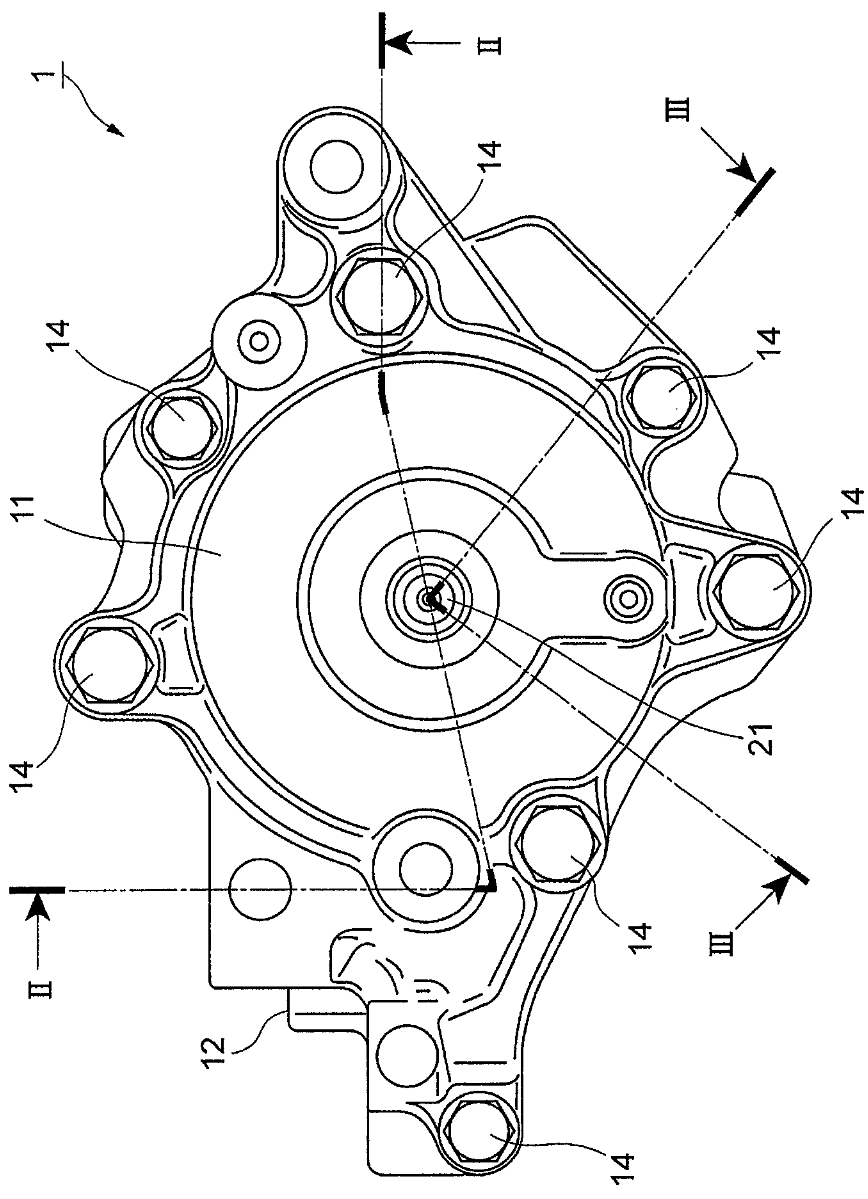


FIG. 2

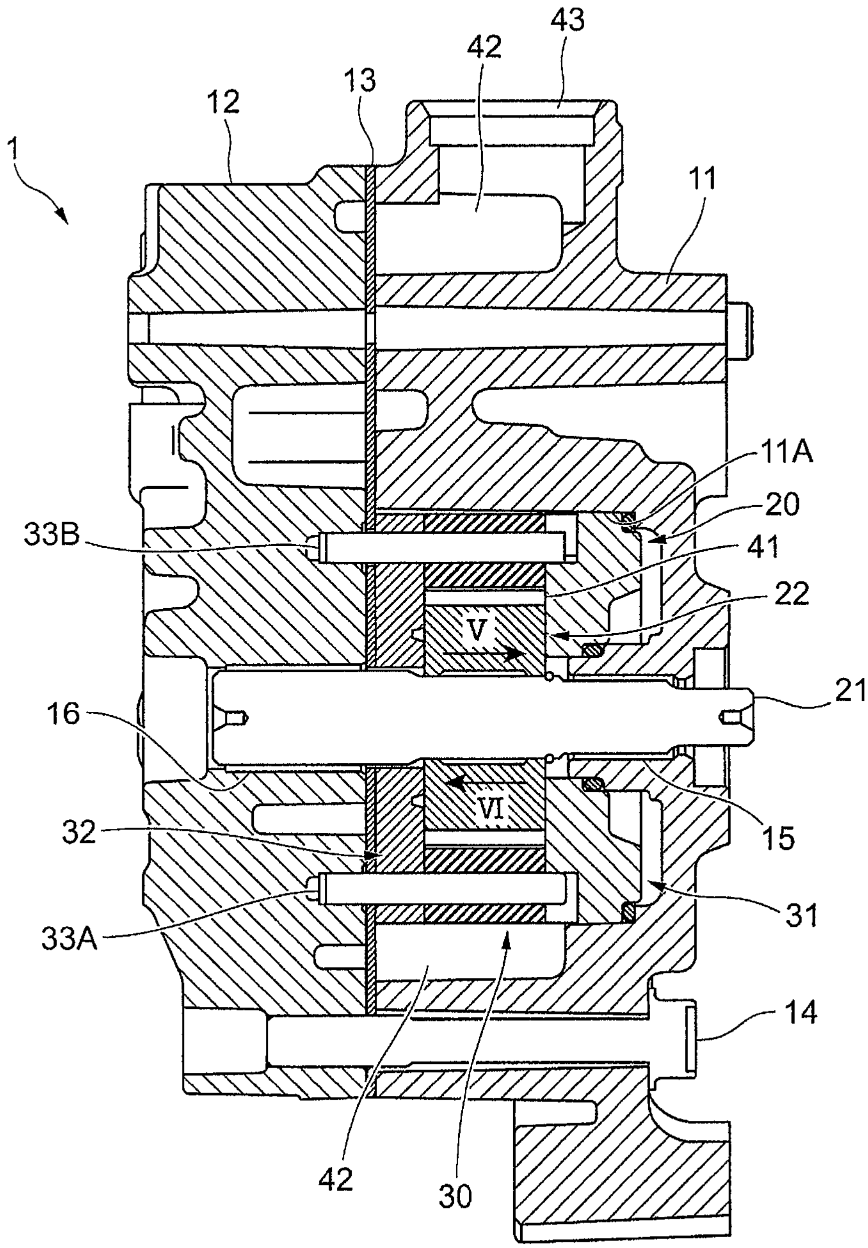
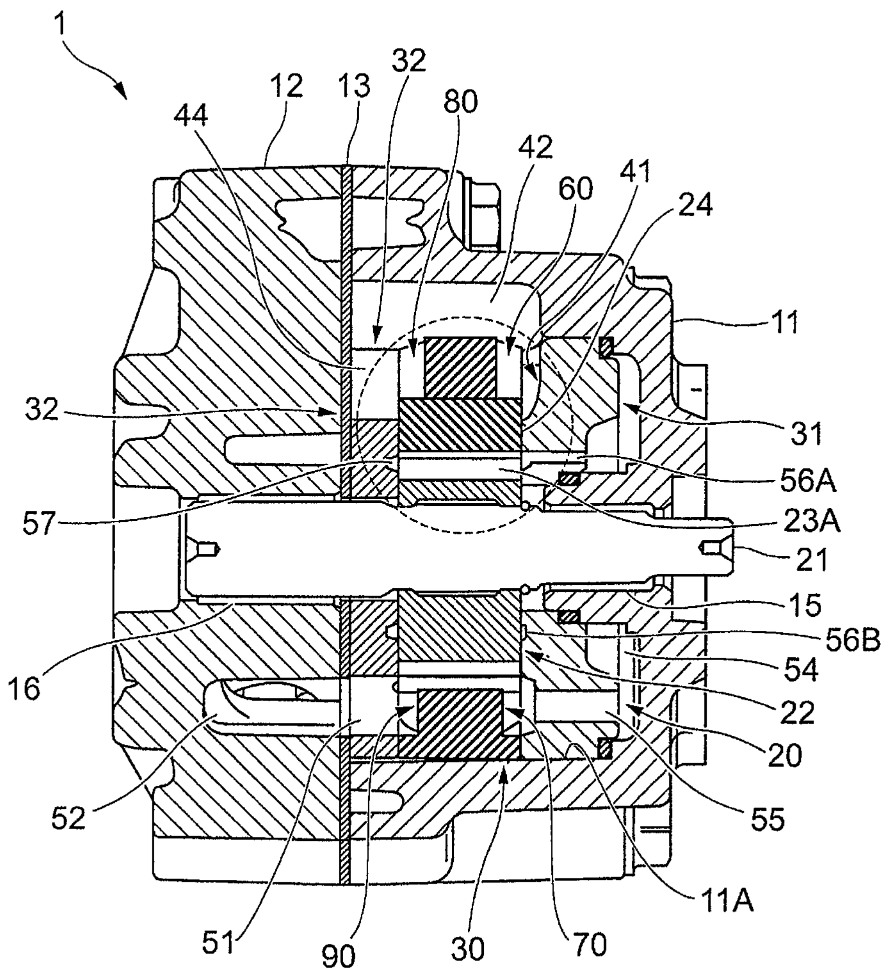


FIG. 3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11
32
31
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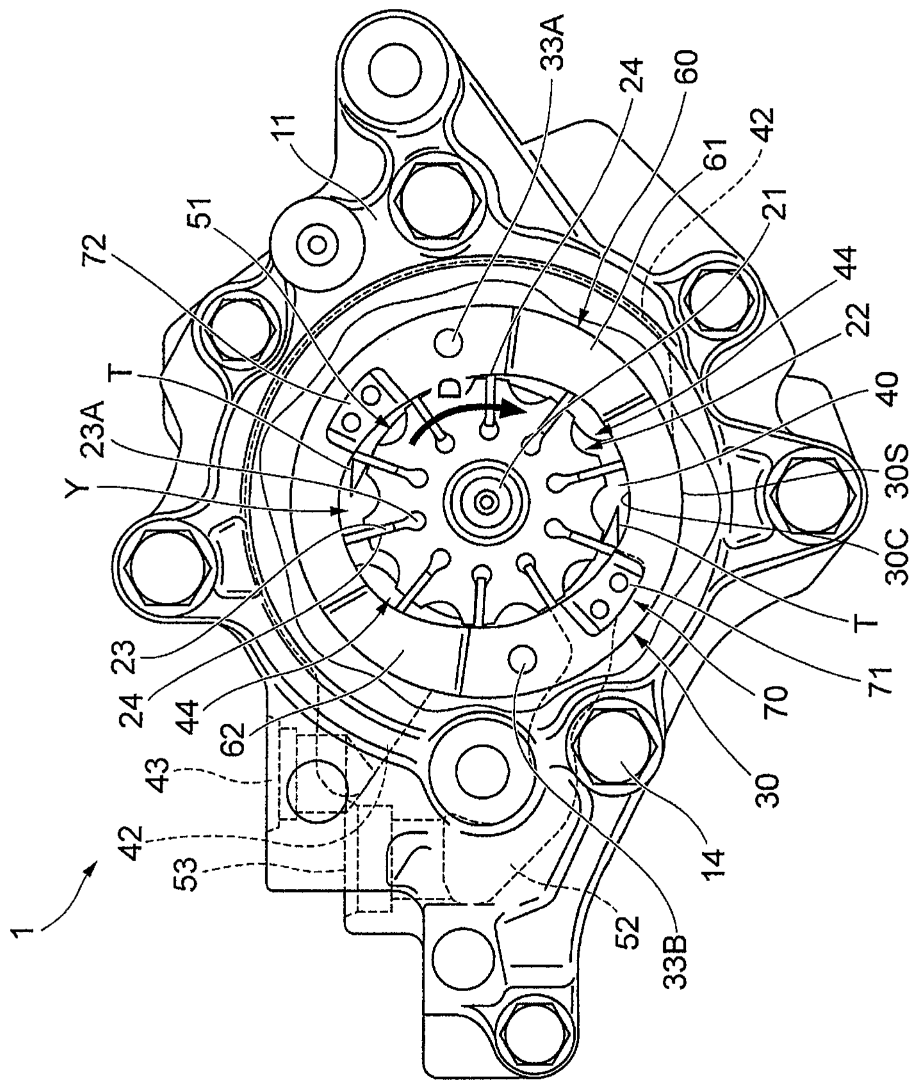
54
22
20
52
55
11A
51
90
30
70

FIG. 4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33A
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FIG. 5

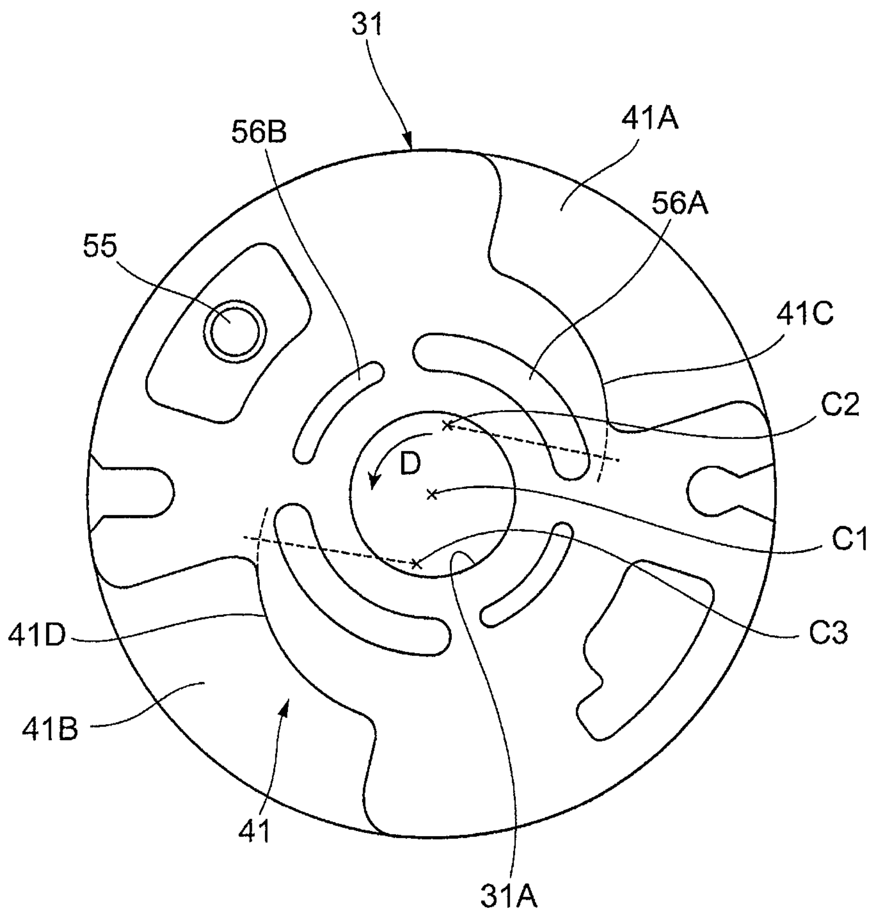
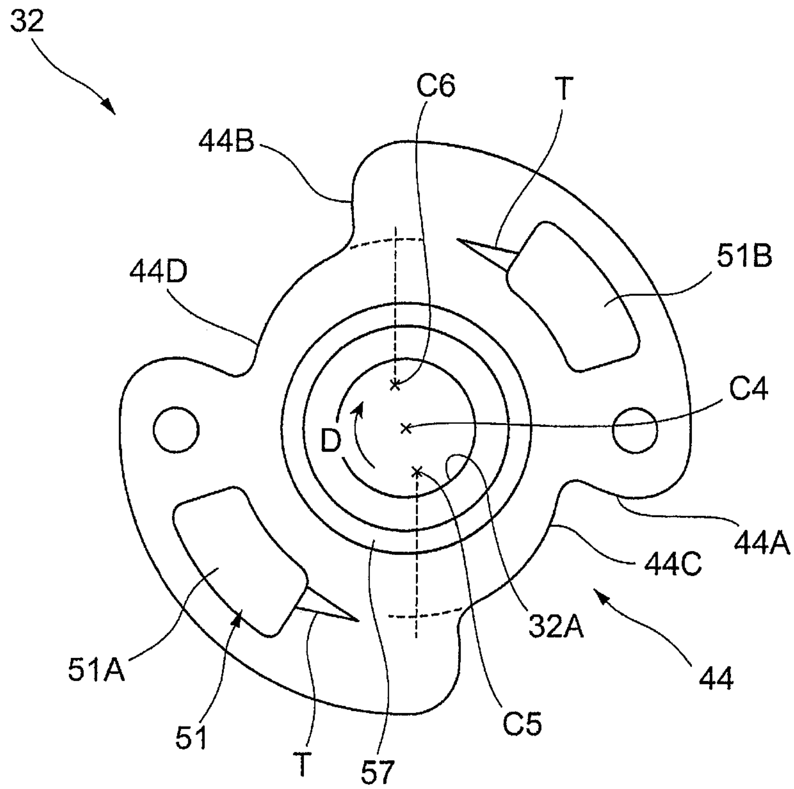


FIG. 6



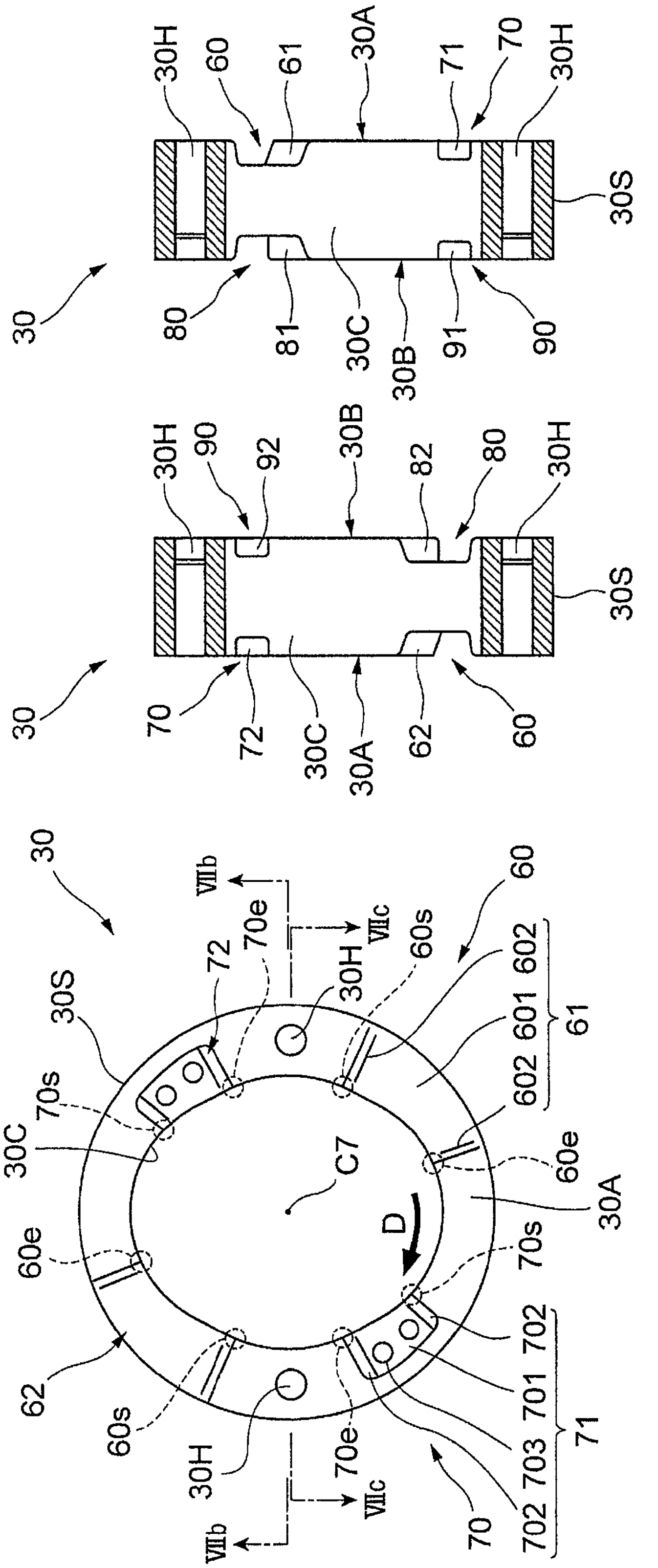


FIG. 7C

FIG. 7B

FIG. 7A

FIG. 8

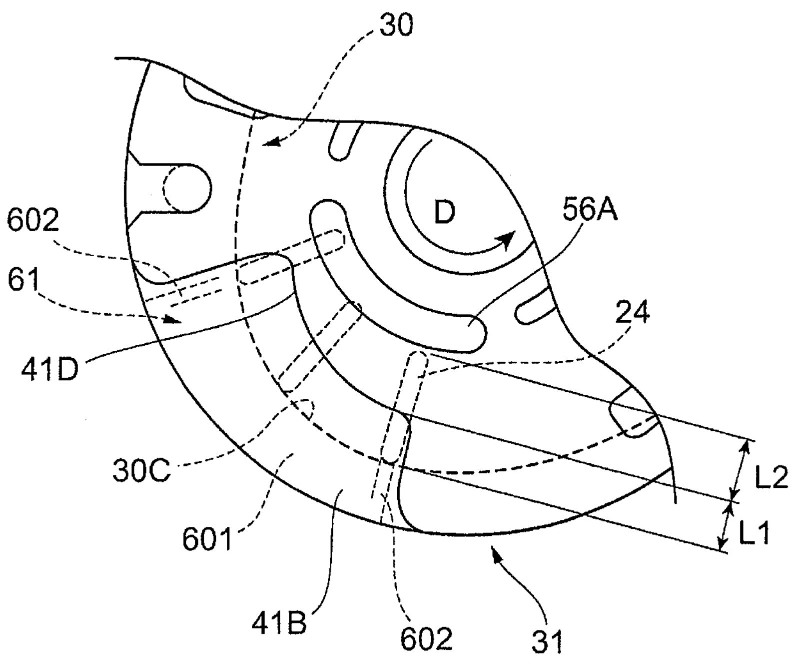


FIG. 9

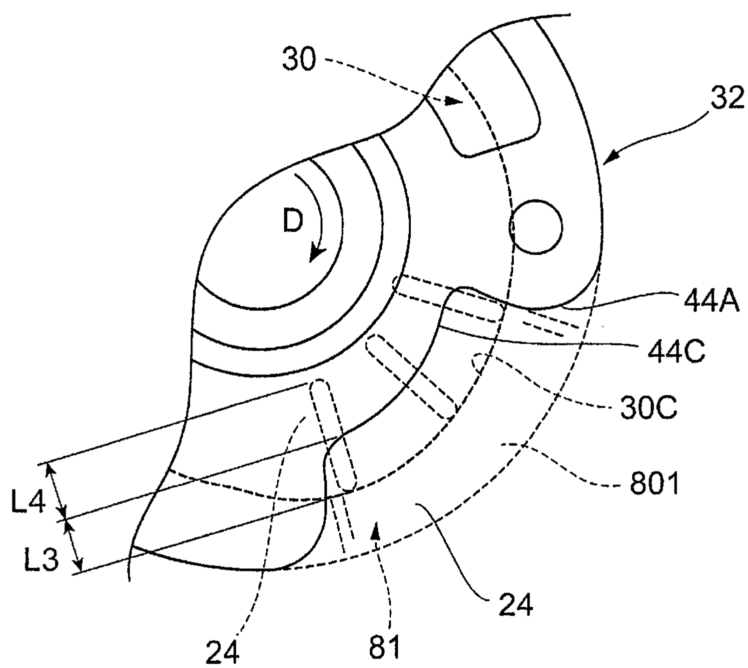


FIG. 10

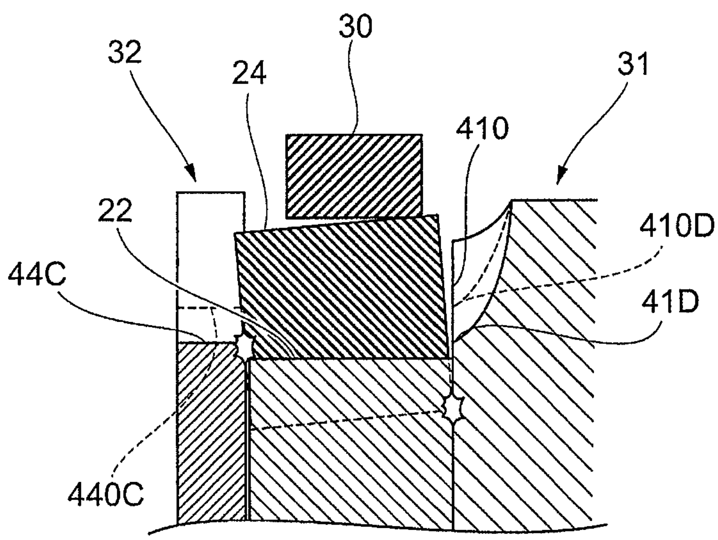
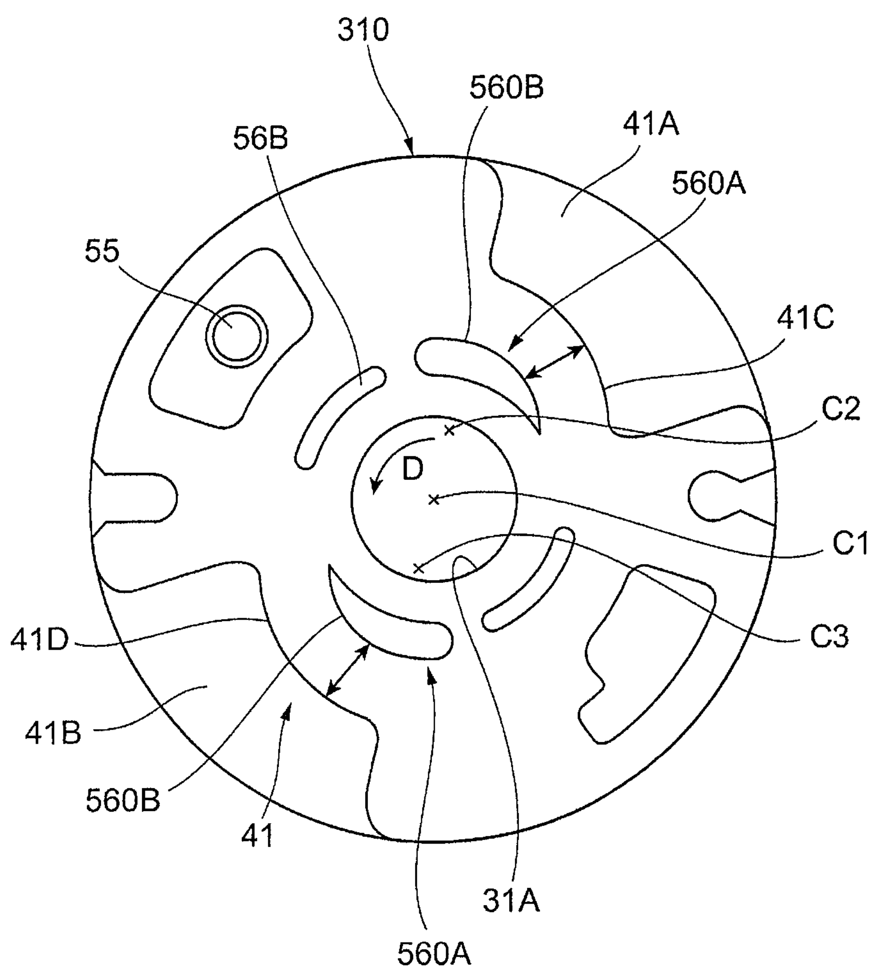


FIG. 11



VANE PUMP

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based on and claims priority under 35 USC 119 from Japanese Patent Application No. 2013-260876 filed on Dec. 18, 2013, the entire content of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Technical Field

The present invention relates to a vane pump.

2. Related Art

A vane pump includes a rotating rotor, a cam ring that is arranged to surround the rotor, a plurality of vanes (wings) that are slidably held by a plurality of vane grooves which are disposed in a radiation direction of the rotor, and a plurality of pump chambers that are partitioned by the two vanes which are adjacent in the vicinity of the rotor. The volume of the pump chamber is repeatedly increased and decreased by the rotation of the rotor. A plurality of suction ports are disposed in a side plate or the like at a position that corresponds to the expansion process of the pump chamber and a plurality of discharge ports are disposed in the side plate or the like at a position that corresponds to the contraction process. The vane pump supplies, for example, a working oil to a target device that is a supply target (refer to, for example, JP-A-2007-162554).

SUMMARY OF THE INVENTION

The suction area where the working oil is suctioned increases when a position of an end portion of the rotor on the rotation shaft side becomes closer to the rotation shaft and an opening of a supply unit of the side plate is widened. In this manner, the amount of suction of the working oil is increased and the suction efficiency is improved. However, the area where the vanes are supported by the side plate or the like is decreased as the supply unit becomes closer to the rotation shaft. As a result, the vanes become unstable in posture and, for example, the vanes are inclined such that corners of the vanes come into contact with the side plate or the like. This may result in burning of the vanes and the side plate or an abnormal noise.

An illustrative aspect of the invention is to suppress instability of a posture of a vane and improve suction efficiency of a supply unit of a side plate.

According to an aspect of the invention, there is provided a vane pump including a rotor that is coupled with a rotation shaft to rotate, a plurality of vanes that are slidably held by a plurality of vane grooves which are disposed in a radiation direction in an outer circumferential portion of the rotor, a cam ring that is arranged to surround the rotor and the plurality of vanes, and a side plate that covers the cam ring and has a supply unit which supplies a working fluid into the cam ring between the cam ring, an outer circumference of the side plate being recessed to a radially inner side of the rotation shaft to form the supply unit, in which an outer circumference of the supply unit and an inner circumference of the cam ring are shaped along each other.

In the aspect, the vane pump may further include another side plate that is arranged on a side opposite to the side plate across the cam ring to cover the cam ring and has another supply unit which supplies the working fluid into the cam ring between the cam ring, an outer circumference of said another side plate being recessed to the radially inner side of the rotation shaft to form said another supply unit, in which an outer circumference of said another supply unit and the inner circumference of the cam ring are shaped along each other.

In the aspect, the side plate may have a through-hole, on the radially inner side of the rotation shaft compared to the supply unit, which supplies the working fluid pressing the plurality of vanes to allow the plurality of vanes to protrude from the rotor into the cam ring, and a radially outer side of the rotation shaft in the through-hole may be shaped along the inner circumference of the cam ring.

According to any aspect of the invention, instability of the posture of the vanes can be suppressed, and the suction efficiency of the supply unit of the side plate can be improved.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an overall view of a vane pump to which this configuration example is applied.

FIG. **2** is a cross-sectional view taken along line II-II of FIG. **1**.

FIG. **3** is a cross-sectional view taken along line III-III of FIG. **1**.

FIG. **4** is a view illustrating an inner portion of a pump unit.

FIG. **5** is an overall view of an inner side plate of this configuration example.

FIG. **6** is an overall view of an outer side plate of this configuration example.

FIGS. **7**A to **7**C are views illustrating a cam ring of this configuration example in detail.

FIG. **8** is a view illustrating an operation of a vane in the vicinity of a suction port of this configuration example.

FIG. **9** is a view illustrating the operation of the vane in the vicinity of the suction port of this configuration example.

FIG. **10** is a view illustrating an inclination of the vane of this configuration example.

FIG. **11** is an overall view of an inner side plate of another configuration example.

DETAILED DESCRIPTION OF THE INVENTION

Hereinafter, configuration examples of the invention will be described in detail with reference to the accompanying drawings.

FIG. **1** is an overall view of a vane pump **1** to which this configuration example is applied. FIG. **2** is a cross-sectional view taken along line II-II of FIG. **1**. FIG. **3** is a cross-sectional view taken along line of FIG. **1**. FIG. **4** is a view illustrating an inner portion of a pump unit **20**.

Description of Configuration and Function of Vane Pump **1**

The vane pump **1** is driven by, for example, power of an internal combustion engine of a vehicle, and is used as an oil pump that supplies a working oil as an example of a working fluid to fluid equipment such as a hydraulic power steering and a hydraulic continuously variable transmission.

The vane pump **1** shown in FIG. **1** is a fixed capacity type vane pump. The vane pump **1** of this configuration example includes a housing **11**, a cover plate **12** that covers an opening of the housing **11**, and the pump unit **20** that is accommodated inside the housing **11** and the cover plate **12**.

As shown in FIG. **2**, the housing **11** has an accommodation unit **11**A that has a shape of a concave portion and accommodates the pump unit **20**. The housing **11** has a suction inlet **43** that suctions the working oil from outside the apparatus, and a suction passage **42** that forms a passage, in the housing **11**, for the working oil suctioned from the suction inlet **43**. The suction passage **42** is disposed to face one end side suction port **60** and the other end side suction port **80** (described later) of a cam ring **30** (refer to FIG. **3** described later).

Further, the housing **11** forms a high-pressure chamber **54**, in an innermost portion of the accommodation unit **11**A of the housing **11**, which is partitioned by an inner side plate **31** (described later) as shown in FIG. **3**.

The cover plate **12** covers the opening of the accommodation unit **11**A of the housing **11** as shown in FIG. **2**. The cover plate **12** and the housing **11** are fastened by a plurality of bolts **14** and are fixed. A seal plate **13** is pinched between the cover plate **12** and the housing **11**. The seal plate **13** covers and seals a plurality of passage grooves and concave portions formed in the housing **11** and the cover plate **12**.

Positioning pins **33**A and **33**B respectively pass through the cover plate **12** and the pump unit **20** to be mounted thereon and relative positioning of each of the members is performed in a circumferential direction.

The pump unit **20** has a rotation shaft **21**, a rotor **22** that is fixed to the rotation shaft **21**, a plurality of vanes **24** (refer to FIGS. **3** and **4**) that are slidably disposed in the rotor **22**, the cam ring **30** that surrounds the rotor **22** and the vanes **24**, and a pair of the inner side plate **31** and an outer side plate **32** that pinches the rotor **22**, the vanes **24**, and the cam ring **30** on both sides of the rotation shaft **21** in an axial direction.

The rotation shaft **21** is rotatably supported by a first bearing **15** that is disposed in the housing **11** and a second bearing **16** that is disposed in the cover plate **12**. A serration (not shown) is formed in the rotation shaft **21**, and the rotation shaft **21** is fixedly coupled with the rotor **22** via the serration. The rotor **22** rotates when the rotation shaft **21** receives driving from a driving source out of the vane pump **1** such as the internal combustion engine.

As shown in FIG. **4**, the rotation shaft **21** (rotor **22**) is configured to rotate in a D direction in FIG. **4** in this configuration example.

As shown in FIG. **4**, the rotor **22** is a member that has a circular outline, and has a plurality of concavities and convexities disposed on an outer circumferential surface thereof in this configuration example. Vane grooves **23** are formed at a plurality of positions of the rotor **22** in the circumferential direction. Herein, the outer circumferential surface of the rotor **22** is shaped to protrude toward a radially outer side at parts in the circumferential direction where the vane grooves **23** are formed and to be recessed toward a radially inner side between the two vane grooves **23** adjacent to each other in the circumferential direction.

The plurality of vane grooves **23** are disposed along the circumferential direction in an outer circumferential portion of the rotor **22**. Each of the vane grooves **23** is disposed along a radiation direction (radial direction). The vane grooves **23** are grooves open to the outer circumferential surface and both side surfaces of the rotor **22**. The vane groove **23** accommodates each of the vanes **24** and holds the accommodated vane **24** to be slidable in the radial direction. The vane groove **23** has a bottom portion space **23**A, which is wide in the circumferential direction, in a bottom portion (center side of the rotor **22**).

The vanes **24** are plate-shaped members, and are mounted on the respective vane grooves **23** of the rotor **22** as described above.

Leading ends of the vanes **24** are pressed to and abut against an inner circumferential surface **30**C (described later) of the cam ring **30** due to pressure of a high-pressure discharge oil that is introduced to the bottom portion spaces **23**A of the vane grooves **23**. A mechanism that allows the vanes **24** to abut against the inner circumferential surface **30**C by using the pressure of the high-pressure discharge oil will be described in detail later.

When the rotor **22** rotates, the vanes **24** slide in the radial direction in the vane grooves **23**, and is repeatedly moved to be pushed out of the vane grooves **23** or to be pushed into the vane grooves **23**. In this case, during a single rotation of the rotor **22**, the vanes **24** are pushed most deeply into the vane grooves **23** when the vanes **24** are at a rotation angle directed from a discharge area (described later) to a suction area (described later). When the vanes **24** are at a rotation angle directed from the suction area to the discharge area, the vanes **24** are pushed most out of the vane grooves **23**.

As shown in FIG. **4**, the cam ring **30** has a tubular shape, and has the inner circumferential surface **30**C that forms a cam surface with a cam curve which approximates an ellipse, and a circular outer circumferential surface **30**S. The cam ring **30** is disposed at a position where the outer circumferential surface **30**S faces the suction passage **42** formed in the housing **11**.

The cam ring **30** accommodates the rotor **22** and the vanes **24** in a tubular inner portion, that is, an area surround by the inner circumferential surface **30**C. An oil chamber Y is formed between the inner circumferential surface **30**C and the rotor **22**. Herein, the inner circumferential surface **30**C of the cam ring **30** is a surface approximating an ellipse as described above, and the rotor **22** has a circular outline. Accordingly, the oil chamber Y has an area with a wide gap in the axial direction between the inner circumferential surface **30**C and the outer circumferential surface of the rotor **22** and an area with a narrow gap in the axial direction between the inner circumferential surface **30**C and the outer circumferential surface of the rotor **22**.

As described above, the cam ring **30**, the rotor **22**, and the vanes **24** are pinched by the inner side plate **31** and the outer side plate **32** on both end sides in the axial direction. Each pump chamber **40** is formed by the inner side plate **31**, the outer side plate **32**, the inner circumferential surface **30**C of the cam ring **30**, the outer circumferential surface of the rotor **22**, and the two vanes **24** adjacent to each other.

A configuration and a function of the cam ring **30** will be described in detail later. With Regard to Inner Side Plate **31**

FIG. **5** is an overall view of the inner side plate **31** of this configuration example. FIG. **5** shows the inner side plate **31** viewed from an arrow V shown in FIG. **2**.

The inner side plate **31**, which is an example of a side plate, is a member that has a disk-shaped outline as shown in FIG. **5**, and has a shaft hole **31**A, through which the rotation shaft **21** (refer to FIG. **4**) passes, in a central portion. In addition, the inner side plate **31** has a suction port **41** and a high-pressure oil supply port **55** in an outer circumferential portion. The inner side plate **31** further has a high-pressure oil introduction port **56**A and a groove **56**B on a radially inner side compared to the suction port **41** and the high-pressure oil supply port **55** and in the vicinity of the shaft hole **31**A.

The inner side plate **31** is disposed in the accommodation unit **11**A of the housing **11** and is mounted to face one side portion of the cam ring **30** in the axial direction (refer to FIGS. **2** and **3**).

The suction port **41**, which is an example of a supply unit, is formed as a concave portion that is recessed in the axial direction in the outer circumferential portion of the inner side plate **31**. In this configuration example, the suction port

41 is configured to have a pair of first suction port **41**A and a second suction port **41**B that are arranged at two positions facing each other in a diametrical direction. The suction inlet **43** (refer to FIG. **4**) is allowed to communicate with the first suction port **41**A and the second suction port **41**B via the suction passage **42** (refer to FIG. **4**) that is disposed in the housing **11**. The first suction port **41**A and the second suction port **41**B form a path for the working oil supplied to the pump chamber **40** (refer to FIG. **4**) when the rotor **22** rotates.

Herein, the first suction port **41**A and the second suction port **41**B can be considered as parts where the outer circumferential surface of the inner side plate **31** is recessed to the radially inner side.

An inner side end portion **41**C, which is an end portion of the first suction port **41**A on the radially inner side, is formed to have an arc shape. Specifically, the inner side end portion **41**C is shaped to have an arc, which is smaller in radius than an outer circumferential circle of the inner side plate **31**, about a center position C2, which is a position shifted to the first suction port **41**A side from a center position C1 (corresponding to a rotation center of the rotor **22**) of the outer circumferential circle of the inner side plate **31**.

An inner side end portion **41**D, which is an end portion of the second suction port **41**B positioned on the radially inner side of the rotation shaft **21**, is formed to have an arc shape. Specifically, the inner side end portion **41**D is shaped to have an arc, which is smaller in radius than the outer circumferential circle of the inner side plate **31**, about a center position C3, which is a position shifted to the second suction port **41**B side from the center position C1 of the inner side plate **31**.

The shapes of the inner side end portion **41**C and the inner side end portion **41**D can be considered as a part of an elliptical shape.

In a state where the inner side plate **31** is mounted on the cam ring **30**, each of the inner side end portion **41**C of the first suction port **41**A and the inner side end portion **41**D of the second suction port **41**B, which are examples of an outer circumference of the supply unit, has a shape that has a part along the inner circumferential surface **30**C of the cam ring **30**. In other words, each of the inner side end portion **41**C of the first suction port **41**A and the inner side end portion **41**D of the second suction port **41**B has a shape similar to the offset of the inner circumferential surface **30**C of the cam ring **30**. A relationship between the inner side end portion **41**C of the first suction port **41**A or the inner side end portion **41**D of the second suction port **41**B and the inner circumferential surface **30**C of the cam ring **30** will be described in detail later.

The high-pressure oil supply port **55** allows a discharge port **51** (described later) that is disposed in the outer side plate **32** to communicate with the high-pressure chamber **54**. The high-pressure oil supply port **55** constitutes a passage through which the working oil, which is discharged from the discharge port **51** of the outer side plate **32** when the rotor **22** rotates, is supplied to the high-pressure chamber **54**.

The high-pressure oil introduction port **56**A, which is formed to pass through the inner side plate **31**, is an arc-shaped groove about the center position C1. In this configuration example, the high-pressure oil introduction port **56**A is disposed at two positions opposing each other around the shaft hole **31**A on the same diameter of the inner side plate **31**. The high-pressure oil introduction port **56**A introduces the high-pressure discharge oil in the high-pressure chamber **54** to the bottom portion space **23**A (refer to FIG. **4**) of the vane groove **23** (refer to FIG. **4**). The high-pressure oil introduction port **56**A is set to communicate with the bottom portion space **23**A of the vane groove **23** no matter which rotation position the rotor **22** has.

The groove **56**B is an arc-shaped groove that is formed in the inner side plate **31**. In this configuration example, the groove **56**B is disposed at two positions pinched by the two high-pressure oil introduction ports **56**A formed in the inner side plate **31**. The grooves **56**B communicate with the bottom portion spaces **23**A (refer to FIG. **4**) of some of the vane grooves **23** (refer to FIG. **4**) in the circumferential direction of the rotor **22**. The grooves **56**B are set to communicate with the bottom portion spaces **23**A of the vane grooves **23** no matter with rotation position the rotor **22** has.

With Regard to Outer Side Plate **32**

FIG. **6** is an overall view of the outer side plate **32** of this configuration example. FIG. **6** shows the outer side plate **32** viewed from an arrow VI shown in FIG. **2**.

The outer side plate **32**, which is an example of another side plate, is a member having a disk-shaped outline as shown in FIG. **6**, and has a shaft hole **32**A, through which the rotation shaft **21** (refer to FIG. **4**) passes, in a central portion. In addition, the outer side plate **32** has a suction port **44** and the discharge port **51** in an outer circumferential portion. In addition, the outer side plate **32** has a back pressure groove **57** in the vicinity of the shaft hole **32**A. The outer side plate **32** further has groove portions T that communicate with the discharge port **51**.

The outer side plate **32** is disposed in the accommodation unit **11**A of the housing **11**, and is mounted to face a side portion of the cam ring **30** on the side opposite to the inner side plate **31** in the axial direction (refer to FIGS. **2** and **3**).

The suction port **44**, which is an example of another supply unit, is formed as an opening portion that is recessed to the radially inner side in an outer circumferential portion of the outer side plate **32**. In this configuration example, the suction port **44** is configured to have a pair of a first suction port **44**A and a second suction port **44**B that are arranged at two positions facing each other in the diametrical direction. The suction inlet **43** (refer to FIG. **4**) is allowed to communicate with the first suction port **44**A and the second suction port **44**B via the suction passage **42** (refer to FIG. **4**) that is disposed in the housing **11**. The first suction port **44**A and the second suction port **44**B form a path for the working oil toward the pump chamber **40** (refer to FIG. **4**) when the rotor **22** rotates.

An inner side end portion **44**C, which is an end portion of the first suction port **44**A on the radially inner side of the rotation shaft **21**, is formed to have an arc shape. Specifically, the inner side end portion **44**C is shaped to have an arc, which is smaller in radius than an outer circumferential circle of the outer side plate **32**, about a center position C5, which is a position shifted to the first suction port **44**A side from a center position C4 (corresponding to the rotation center of the rotor **22**) of the outer circumferential circle of the outer side plate **32**.

An inner side end portion **44**D, which is an end portion of the second suction port **44**B on the radially inner side of the rotation shaft **21**, is formed to have an arc shape. Specifically, the inner side end portion **44**D is shaped to have an arc, which is smaller in radius than the outer circumferential circle of the outer side plate **32**, about a center position C6, which is a position shifted to the second suction port **44**B side from the center position C4 of the outer side plate **32**.

In a state where the outer side plate **32** is mounted on the cam ring **30**, each of the inner side end portion **44**C of the first suction port **44**A and the inner side end portion **44**D of the second suction port **44**B, which are examples of an outer circumference of the other supply unit, has a shape that has a part along the inner circumferential surface **30**C of the cam ring **30**. In other words, each of the inner side end portion **44**C of the first suction port **44**A and the inner side end portion **44**D of the second suction port **44**B has a shape similar to the offset of the inner circumferential surface **30**C of the cam ring **30**. A relationship between the inner side end portion **44**C of the first suction port **44**A or the inner side end portion **44**D of the second suction port **44**B and the inner circumferential surface **30**C of the cam ring **30** will be described in detail later.

The discharge port **51** is configured to have an opening that is formed to pass through the outer side plate **32**. In this configuration example, the discharge port **51** is configured to have a first discharge port **51**A and a second discharge port **51**B. The first discharge port **51**A and the second discharge port **51**B are allowed to communicate with a discharge outlet **53** (refer to FIG. **4**) of the vane pump **1** via a discharge passage **52** (refer to FIG. **4**) that is disposed in the cover plate **12** such that a discharge path for the working oil from the pump chamber **40** (refer to FIG. **4**) is formed when the rotor **22** rotates.

The back pressure groove **57** is a groove with an annular shape as shown in FIG. **6**. The back pressure groove **57** is disposed to communicate with the bottom portion space **23**A of the vane, groove **23** no matter which rotation position the rotor **22** has. The back pressure groove **57** communicates with the bottom portion spaces **23**A of the entire vane grooves **23** of the rotor **22** (refer to FIG. **4**). Furthermore, the back pressure groove **57** communicates also with the high-pressure chamber **54** via the high-pressure oil introduction port **56**A (refer to FIG. **3**) of the inner side plate **31**.

As shown in FIG. **6**, the groove portions T are grooves that communicate with the discharge port **51** formed in the outer side plate **32**. The groove portions T are positioned on a front side (upstream side) compared to each discharge port **51** (first discharge port **51**A and second discharge port **51**B) in a direction of rotation of the rotor **22**.

In the vane pump **1** to which this configuration example is applied, the groove portion T is disposed in the outer side plate **32**, and thus the pump chamber **40** (refer to FIG. **4**) reaches the groove portion T before reaching the discharge port **51** when the pump chamber **40** moves to the discharge port **51**. Also, an initiation point of communication between the pump chamber **40** and the discharge port **51** is configured to be earlier than in a case where the groove portion T is not provided. As such, in the vane pump **1** of this configuration example, the length of time of the communication between the pump chamber **40** and the discharge port **51** is longer than in a configuration where the groove portion T is not provided. As a result, in the vane pump **1** of this configuration example, a surge pressure in the pump chamber **40** is alleviated and generation of an abnormal noise is reduced.

With Regard to Cam Ring **30**

FIGS. **7**A to **7**C are views illustrating the cam ring **30** of this configuration example in detail.

FIG. **7**A is a side view of the cam ring **30**. FIG. **7**B is a cross-sectional view of the cam ring **30** taken along line VIIb-VIIb of FIG. **7**A, and FIG. **7**C is a cross-sectional view of the cam ring **30** taken along line VIIc-VIIc of FIG. **7**A.

The cam ring **30** shown in FIG. **7**A, which has a tubular shape, has the inner circumferential surface **30**C that forms the cam surface with the cam curve which approximate an ellipse as described above, and the circular outer circumferential surface **30**S. In addition, the cam ring **30** has one end side portion **30**A that has an annular shape in one side portion of the rotor **22** in the axial direction, and the other end side portion **30**B (refer to FIG. **7**B) that has an annular shape in the other side portion. The cam ring **30** further has pin holes **30**H, through which a positioning pin **33**A and a positioning pin **33**B (refer to FIG. **4**) pass respectively.

With Regard to One End Side Portion **30**A

As shown in FIG. **7**A, the one end side suction port **60** that constitutes a suction path for the working oil toward the pump chamber **40** (refer to FIG. **4**) from the outer circumferential surface **30**S into the inner circumferential surface **30**C, and one end side discharge port **70** that constitutes the suction path for the working oil from the pump chamber **40** are formed in the one end side portion **30**A.

In this configuration example, the one end side suction port **60** is configured to have a first suction port **61** and a second suction port **62**. In addition, in this configuration example, the one end side discharge port **70** is configured to have a pair of a first discharge port **71** and a second discharge port **72**.

The first suction port **61** and the first discharge port **71** are one set and the second suction port **62** and the second discharge port **72** are one set, respectively fulfilling a series of operations of the suction of the working oil toward the pump chamber **40** and the discharge of the working oil from the pump chamber **40**.

In the following description, the first suction port **61** and the second suction port **62** are collectively referred to as the "one end side suction port **60**" when not particularly distinguished, and the first discharge port **71** and the second discharge port **72** are collectively referred to as the "one end side discharge port **70**" when not particularly distinguished.

With Regard to the Other End Side Portion **30**B

As shown in FIGS. **7**B and **7**C, the other end side suction port **80** that constitutes a suction path for the working oil toward the pump chamber **40** (refer to FIG. **4**), and the other end side discharge port **90** that constitutes the discharge path for the working oil from the pump chamber **40** are formed in the other end side portion **30**B.

In this configuration example, the other end side suction port **80** is configured to have a first suction port **81** and a second suction port **82**. In addition, in this configuration example, the other end side discharge port **90** is configured to have a pair of a first discharge port **91** and a second discharge port **92**.

The first suction port **81** and the first discharge port **91** are one set and the second suction port **82** and the second discharge port **92** are one set, respectively fulfilling a series of operations of the suction of the working oil toward the pump chamber **40** and the discharge of the working oil from the pump chamber **40**.

In the following description, the first suction port **81** and the second suction port **82** are collectively referred to as the "other end side suction port **80**" when not particularly distinguished, and the first discharge port **91** and the second discharge port **92** are collectively referred to as "the other end side discharge port **90**" when not particularly distinguished.

The other end side suction port **80** is arranged in the other end side portion **30**B with the one end side suction port **60**, which is formed in the one end side portion **30**A, at front and back positions. Specifically, the first suction port **81** and the first suction port **61** are arranged at the front and back positions as shown in FIG. **7**C. In addition, the second suction port **82** and the second suction port **62** are arranged at the front and back positions as shown in FIG. **7**B.

In detail, the first suction port **81** and the first suction port **44**A face each other and the first suction port **61** and the second suction port **41**B face each other in a state where the cam ring **30** is pinched by the inner side plate **31** and the outer side plate **32**. Accordingly, the first suction port **44**A, the first suction port **81**, the first suction port **61**, and the second suction port **41**B have an overlapping positional relationship in the circumferential direction.

Likewise, the second suction port **82** and the second suction port **44**B face each other and the second suction port **62** and the first suction port **41**A face each other. Accordingly, the second suction port **44**B, the second suction port **82**, the second suction port **62**, and the first suction port **41**A have an overlapping positional relationship in the circumferential direction.

The other end side discharge port **90** is arranged in the other end side portion **30**B with the one end side discharge port **70**, which is formed in the one end side portion **30**A, at front and back positions. Specifically, the first discharge port **91** and the first discharge port **71** are arranged at the front and back positions as shown in FIG. **7**C. In addition, the second discharge port **92** and the second discharge port **72** are arranged at the front and back positions as shown in FIG. **7**B.

The one end side suction port **60** and the other end side suction port **80**, and the one end side discharge port **70** and the other end side discharge port **90** have the same shape although respectively formed surfaces differ in the other end side portion **30**B and the one end side portion **30**A. Accordingly, in the following description, the one end side suction port **60** and the one end side discharge port **70** will be described as representative examples, and description of the other end side suction port **80** and the other end side discharge port **90** will be omitted.

With Regard to Configuration and Function of One End Side Suction Port **60**

The one end side suction port **60** (first suction port **61** and second suction port **62**) is formed as a groove that is disposed to be open in the radial direction from the inner circumferential surface **30**C to the outer circumferential surface **30**S. The one end side suction port **60** is configured to have a bottom surface portion **601** and an inclined portion **602**.

The bottom surface portion **601** is a flat surface that is recessed in a thickness direction when compared to the other surface (hereinafter, referred to as a principal surface) of the one end side portion **30**A. The bottom surface portion **601** is formed to have an increasing width in the circumferential direction from the inner circumferential surface **30**C to the outer circumferential surface **30**S.

The inclined portion **602** is a surface that is inclined from the principal surface of the one end side portion **30**A toward the bottom surface portion **601**, and is disposed to extend from the inner circumferential surface **30**C toward the outer circumferential surface **30**S. Two inclined portions **602** are arranged to face each other in the circumferential direction. The facing inclined portions **602** are formed to have an increasing gap from the inner circumferential surface **30**C toward the outer circumferential surface **30**S.

Furthermore, the first suction port **61** and the second suction port **62** are disposed at positions facing each other in the diametrical direction through a center position C7 (corresponding to the rotation center of the rotor **22**) of the cam ring **30**. In other words, a pair of the first suction port **61** and the second suction port **62** are arranged on a straight line through the center position C7 of the cam ring **30**.

In this configuration example, the pair of the first suction port **61** and the second suction port **62** are arranged in the diametrical direction. As such, an eccentric load that is applied to, for example, the rotation shaft **21** of the rotor **22** can be reduced.

As shown in FIG. **7**A, suction initiation positions **60***s* are formed in respective end portions of the first suction port **61** and the second suction port **62** on the upstream side in the direction of rotation (D direction in the drawing) of the rotor **22** (refer to FIG. **4**). In addition, suction completion positions **60***e* are formed in respective end portions of the first suction port **61** and the second suction port **62** on the downstream side in the direction of rotation of the rotor **22**.

The pump chambers **40** (refer to FIG. **4**) that are formed by the adjacent vanes **24** (refer to FIG. **4**) move in the first suction port **61** and the second suction port **62**. The suction of the working oil toward the pump chamber **40** is initiated when the vanes **24** forming the pump chamber **40** reach the suction initiation position **60***s*. The suction of the working oil is completed when the pump chamber **40** passes through the suction completion position **60***e*.

Configuration and Function of One End Side Discharge Port **70**

As shown in FIG. **7**A, the one end side discharge port **70** is formed as a groove that is disposed to be open only to the inner circumferential surface **30**C side. The one end side discharge port **70** is configured to have a bottom surface portion **701**, an inclined portion **702**, and a through-hole **703**.

The bottom surface portion **701** is a flat surface that is recessed in the thickness direction when compared to the principal surface of the one end side portion **30**A.

The inclined portion **702** is a surface that is inclined from the principal surface of the one end side portion **30**A toward the bottom surface portion **701**, and is disposed to extend from the inner circumferential surface **30**C toward the outer circumferential surface **30**S. Two inclined portions **702** are arranged to face each other in the circumferential direction.

The through-hole **703** is formed in the bottom surface portion **701** and passes through to the other end side discharge port **90**. As such, the discharge oil is allowed to communicate with the one end side portion **30**A and the other end side portion **30**B of the cam ring **30** therebetween.

As shown in FIG. **7**A, in the first discharge port **71** and the second discharge port **72**, discharge initiation positions **70***s* are formed in respective end portions of the first discharge port **71** and the second discharge port **72** on the upstream side in the direction of rotation (D direction in the drawing) of the rotor **22** (refer to FIG. **4**). In addition, discharge completion positions **70***e* are formed in respective end portions of the first discharge port **71** and the second discharge port **72** on the downstream side in the direction of rotation of the rotor **22**.

The pump chambers **40** (refer to FIG. **4**) that are formed by the adjacent vanes **24** (refer to FIG. **4**) move in the first discharge port **71** and the second discharge port **72**. The discharge of the working oil from the pump chamber **40** is initiated when the vanes **24** forming the pump chamber **40** reach the discharge initiation positions **70***s*. The discharge of the working oil is completed when the pump chamber **40** passes through the discharge completion positions **70***e*.

The second suction port **62** of the one end side suction port **60** that has the above-described configuration is disposed along a flow path part of the suction passage **42** that extends toward the second suction port **62**. In other words, in this configuration example, the flow path part that extends from the suction passage **42** toward the second suction port **62** and the second suction port **62** are arranged to have a consistent main flow direction of the working oil and are arranged to have angles matching with each other. In this manner, in this configuration example, the working oil that flows through the suction passage **42** flows straightforwardly into the second suction port **62**. As such, in this configuration example, the working oil flows to the second suction port **62** efficiently.

Operation of Vane Pump **1**

In the vane pump **1** that has the above-described configuration, the rotor **22** rotates when the rotation shaft **21** rotates by receiving the driving from, for example, the internal combustion engine (not shown) as shown in FIG. **4**. When the rotor **22** rotates, the leading ends of the plurality of vanes **24** are in a rotating state while being pressed to the inner circumferential surface **30**C on an inner circumference of the cam ring **30**.

Herein, in the vane pump **1**, the working oil that is supplied from the suction inlet **43** is in a state of flowing into the one end side suction port **60** and the other end side suction port **80** of the cam ring **30** via the suction passage **42**. Then, in the suction area on the upstream side in the direction of rotation of the rotor **22**, the working oil from the suction port **41** of the inner side plate **31** and the suction port **44** of the outer side plate **32** is suctioned to the pump chamber **40** that expands when the rotor **22** rotates. The suction area refers to an area where the suction port **41** of the inner side plate **31** and the suction port **44** of the outer side plate **32** are disposed in the circumferential direction.

In the discharge area on the downstream side in the direction of rotation of the rotor **22**, the working oil from the pump chamber **40** that is compressed when the rotor **22** rotates is discharged to the discharge port **51**. The high-pressure discharge oil that is discharged to the discharge port **51** is discharged from the discharge outlet **53** through the discharge passage **52**. The discharge area refers to an area where the discharge port **51** of the outer side plate **32** is disposed in the circumferential direction.

The vane pump **1** to which this configuration example is applied fulfills a pump operation in the above-described manner such that the working oil suctioned by the suction inlet **43** is discharged from the discharge outlet **53**.

Next, an abutting operation of the inner circumferential surface **30**C of the vane **24** of the vane pump **1** according to this configuration example will be descried.

As shown in FIG. **3**, the high-pressure discharge oil that is discharged from the discharge port **51** due to the rotation of the rotor **22** is supplied to the high-pressure chamber **54** through the bottom portion spaces **23**A of some of the vane grooves **23** of the rotor **22** and the high-pressure oil supply port **55**. Furthermore, the high-pressure discharge oil with which the high-pressure chamber **54** is filled is supplied to the annular back pressure groove **57** of the outer side plate **32** via the high-pressure oil introduction port **56**A of the inner side plate **31** and the bottom portion spaces **23**A of some of the vane grooves **23** of the rotor **22**.

The high-pressure discharge oil that is introduced to the bottom portion spaces **23**A of the vane grooves **23** which do not communicate with the high-pressure oil introduction port **56**A of the inner side plate **31** is pushed to fill the groove **56**B of the inner side plate **31**.

The high-pressure discharge oil that is supplied to the annular back pressure groove **57** is in a state of being introduced at the same time to the bottom portion spaces **23**A of the entire vane grooves **23** of the rotor **22** with which the back pressure groove **57** communicates. The leading ends of the vanes **24** are pressed to the inner circumferential surface **30**C of the cam ring **30** due to the pressure of the high-pressure discharge oil which is introduced to the bottom portion spaces **23**A of the vane grooves **23**.

Operation of Vane **24** in Vicinity of Suction Port **41**

FIG. **8** is a view illustrating an operation of the vane **24** in the vicinity of the suction port **41** of this configuration example.

As described above, the first suction port **41**A and the second suction port **41**B of the suction port **41** of the inner side plate **31** have the same shape. In the following description, the operation of the vane **24** in the vicinity of the second suction port **41**B will be described as a representative example, and description of the operation of the vane **24** in the vicinity of the first suction port **41**A will be omitted.

As shown in FIG. **8**, the inner side end portion **41**D of the second suction port **41**B is shaped along the inner circumferential surface **30**C of the cam ring **30**. Accordingly, the distance (length in the radial direction) between the inner side end portion **41**D of the second suction port **41**B and the inner circumferential surface **30**C of the cam ring **30** is constant in the suction area. In other words, an opening with a constant width in the radial direction is formed between the inner side end portion **41**D and the inner circumferential surface **30**C of the cam ring **30**. As such, a period when the length (refer to a length L1) of a part where the vane **24** protrudes from the inner side plate **31** (inner side end portion **41**D) to the radially outer side is constant is present when the vane **24** that rotates when the rotor **22** rotates passes through the suction area. Accordingly, inclination of the vane **24** with respect to the rotation shaft **21** of the rotor **22** is suppressed (described in detail later).

Herein, the second suction port **41**B of the example that is shown can be considered to have a shape in which the area where the length of the part where the vane **24** protrudes from the inner side plate **31** to the radially inner side is constant is formed.

In addition, the second suction port **41**B of the example that is shown can be considered that the upstream side part of the inner side end portion **41**D in the direction of the rotation (D direction in the drawing) of the rotor **22** (refer to FIG. **4**) is shaped along the inner circumferential surface **30**C of the cam ring **30**.

Furthermore, the second suction port **41**B of the example that is shown can be considered that the part of the inner side end portion **41**D that faces the first suction port **61** of the cam ring **30** is shaped along the inner circumferential surface **30**C of the cam ring **30**. In further detail, a part of the inner side end portion **41**D of the second suction port **41**B overlapping with the area where the bottom surface portion **601** of the first suction port **61** is formed in the circumferential direction can be considered to be shaped along the inner circumferential surface **30**C of the cam ring **30**.

Operation of Vane **24** in Vicinity of Suction Port **44**

FIG. **9** is a view illustrating the operation of the vane **24** in the vicinity of the suction port **44** of this configuration example.

As described above, the first suction port **44**A and the second suction port **44**B of the suction port **44** of the outer side plate **32** have the same shape. In the following description, the operation of the vane **24** in the vicinity of the first suction port **44**A will be described as a representative example, and description of the operation of the vane **24** in the vicinity of the second suction port **44**B will be omitted.

As shown in FIG. **9**, the inner side end portion **44**C of the first suction port **44**A is shaped along the inner circumferential surface **30**C of the cam ring **30**. Accordingly, the distance (length in the radial direction) between the inner side end portion **44**C of the first suction port **44**A and the inner circumferential surface **30**C of the cam ring **30** is constant in the suction area. In other words, an opening with a constant width in the radial direction is formed between the inner side end portion **44**C and the inner circumferential surface **30**C of the cam ring **30**. As such a period when the length (refer to a length L3) of a part where the vane **24** protrudes from the outer side plate **32** (inner side end portion **44**C) to the radially outer side is constant is present when the vane **24** that rotates when the rotor **22** rotates passes through the suction area. Accordingly, inclination of the vane **24** with respect to the rotation shaft **21** of the rotor **22** is suppressed (described in detail later).

Herein, the first suction port **44**A of the example that is shown can be considered to have a shape in which the area where the length of the part where the vane **24** protrudes from the outer side plate **32** to the radially outer side is constant is formed.

In addition, the first suction port **44**A of the example that is shown can be considered that the upstream side part of the inner side end portion **44**C in the direction of the rotation (D direction in the drawing) of the rotor **22** (refer to FIG. **4**) is shaped along the inner circumferential surface **30**C of the cam ring **30**.

Furthermore, the first suction port **44**A of the example that is shown can be considered that the part of the inner side end portion **44**C that faces the first suction port **81** of the cam ring **30** is shaped along the inner circumferential surface **30**C of the cam ring **30**. In further detail, a part of the inner side end portion **44**C of the first suction port **44**A overlapping with the area where a bottom surface portion **801** of the first suction port **81** is formed in the circumferential direction can be considered to be shaped along the inner circumferential surface **30**C of the cam ring **30**.

Inclination of Vane **24**

FIG. **10** is a view illustrating the inclination of the vane **24** of this configuration example. In further detail, FIG. **10** shows an area in the circle shown in FIG. **3**.

A configuration in which the inner side end portion **41**D of the second suction port **41**B or the inner side end portion **44**C of the first suction port **44**A is placed closer to the rotation shaft **21** side of the rotor **22** to increase a suction area where the working oil is suctioned can be considered in a case where the efficiency of the suction of the working oil is to be increased in the vane pump **1**. However, when the inner side end portion **41**D of the second suction port **41**B or the inner side end portion **44**C of the first suction port **44**A is simply placed closer to the rotation shaft **21** side of the rotor **22**, the durability of the vane pump **1** may be deteriorated. Herein, the efficiency of the suction simply refers to the amount (volume) of the working oil that passes through the suction port **41** per hour.

Describing specifically with reference to FIG. **10**, the suction area where the working oil is suctioned increases and the efficiency of the suction increases as the inner side end portion **41**D and the inner side end portion **44**C are moved to the rotation shaft **21** (refer to FIG. **4**) of the rotor **22**, that is, the lower side in FIG. **10**. However, when the inner side end portion **41**D and the inner side end portion **44**C are moved to the lower side in the drawing, the length (refer to the length L1 in FIG. **8** and the length L3 in FIG. **9**) of the part where the vane **24** protrudes from the inner side plate **31** or the outer side plate **32** to the radially outer side (upper side in the drawing) increases. As the length of the protruding part increases, the length (refer to a length L2 in FIG. **8** and a length L4 in FIG. **9**) of the area where the vane **24** is supported by the inner side plate **31** or the outer side plate **32** decreases. As a result, the vane **24** is likely to be inclined with respect to the rotation shaft **21** of the rotor **22**.

Accordingly, a corner of the vane **24**, which is a plate-shaped member, is more likely to abut against the inner side plate **31** or the outer side plate **32** than in a case where, for example, radial positions of the inner side end portion **41**D and the inner side end portion **44**C are positioned outside (refer to an inner side end portion **410**D and an inner side end portion **440**C shown by the dashed lines in the drawing). This, for example, may result in damage (burning) to the inner side plate **31** or the outer side plate **32** and the generation of the abnormal noise. Alternatively, the inner side plate **31** or the outer side plate **32** is likely to be worn, and the durability of the vane pump **1** may be deteriorated.

In this configuration example, the positions of the inner side end portion **41**D and the inner side end portion **44**C are determined such that the vane **24** protrudes from the inner side plate **31** or the outer side plate **32** by less than half of the length in the radial direction. In detail, the length L1 in FIG. **8** is smaller than the length L2, or the length L3 in FIG. **9** is smaller than the length L4. More preferably, the positions of the inner side end portion **41**D and the inner side end portion **44**C are determined such that the vane **24** protrudes from the inner side plate **31** or the outer side plate **32** by less than four-tenths of the length in the radial direction.

In this configuration example described above, the length at which the vane **24** protrudes from the inner side plate **31** or the outer side plate **32** to the radially outer side is constant when the rotor **22** rotates to cause the vane **24** to pass through the suction area. In other words, the vane **24** and the inner side plate **31** or the outer side plate **32** have constant relative positions. As such, the position of the vane **24**, which is likely to have an unstable posture when passing through the suction area to suction the working oil, is not shifted with respect to the positions of the inner side plate **31** or the outer side plate **32**, and the inclination of the vane **24** in response to an external force from the inner side plate **31** or the outer side plate **32** is suppressed.

Another Configuration Example

FIG. **11** is an overall view of an inner side plate **310** of another configuration example.

In the following description, the same reference numerals are used in the parts that are identical to those of the inner side plate **31** shown in FIG. **5**, and detailed description thereof will be omitted.

In the above description, the high-pressure oil introduction port **56**A is an arc-shaped groove about the center position C1 which is formed through the inner side plate **31**.

In contrast, according to a high-pressure oil introduction port (through-hole) **560**A shown in FIG. **11**, a radially outer side end portion **560**B, which is an end portion of the rotation shaft **21** positioned on the radially outer side, is shaped along the inner side end portion **41**C of the first suction port **41**A (inner side end portion **41**D of the second suction port **41**B). In detail, the radially outer side end portion **560**B of the high-pressure oil introduction port **560**A is shaped along the inner circumferential surface **30**C of the cam ring **30**. In this manner, the distance (length in the radial direction, refer to the arrow in the drawing) between the radially outer side end portion **560**B and the inner side end portion **41**C of the first suction port **41**A (inner side end portion **41**D of the second suction port **41**B) is constant.

Herein, the pressure of the working oil in the high-pressure oil introduction port **560**A where the high-pressure discharge oil introduced is higher than the pressure of the working oil in the first suction port **41**A. Accordingly, when the distance between the radially outer side end portion

560B and the inner side end portion **41**C of the first suction port **41**A (inner side end portion **41**D of the second suction port **41**B) decreases, the working oil may flow (leak) from the high-pressure oil introduction port **560**A toward the first suction port **41**A.

In this configuration example, the radially outer side end portion **560**B of the high-pressure oil introduction port **560**A is shaped along the inner side end portion **41**C of the first suction port **41**A (inner side end portion **41**D of the second suction port **41**B). Accordingly, when compared to a case in which this configuration is not adopted, the leak of the working oil from the high-pressure oil introduction port **560**A into the first suction port **41**A is suppressed.

In detail, in this configuration example, an area between the high-pressure oil introduction port **560**A and the inner side end portion **41**C of the first suction port **41**A (inner side end portion **41**D of the second suction port **41**B), that is, an area where the working oil is sealed between the high-pressure oil introduction port **560**A and the first suction port **41**A has a constant width. The amount of leak of the working oil can be adjusted by determining the width of the area, and the design of the inner side plate **310** is facilitated with the configuration of this configuration example.

Modification Example

In the above description, each of the inner side end portion **41**C and the inner side end portion **41**D of the inner side plate **31** and the inner side end portion **44**C and the inner side end portion **44**D of the outer side plate **32** are shaped along the inner circumferential surface **30**C of the cam ring **30**. However, any one of the inner side end portion **41**C, the inner side end portion **41**D, the inner side end portion **44**C, and the inner side end portion **44**D may be shaped along the inner circumferential surface **30**C of the cam ring **30**.

For example, the inner side end portion **41**C and the inner side end portion **41**D of the inner side plate **31** may be shaped along the inner circumferential surface **30**C of the cam ring **30** and the inner side end portion **44**C and the inner side end portion **44**D of the outer side plate **32** may be shaped along the arc about the center position C4 of the outer side plate **32**.

In addition, the inner side end portion **44**C and the inner side end portion **44**D of the outer side plate **32** may be shaped along the inner circumferential surface **30**C of the cam ring **30** and the inner side end portion **41**C and the inner side end portion **41**D of the inner side plate **31** may be shaped along the arc about the center position C1 of the inner side plate **31**.

In the above description, the groove portion T is disposed in the outer side plate **32**. However, the groove portion T may be disposed in the inner side plate **31**, and the groove portion T may be disposed in each of the inner side plate **31** and the outer side plate **32**.

What is claimed is:

1. A vane pump comprising:

a rotor that is coupled with a rotation shaft to rotate;

a plurality of vanes that are slidably held by a plurality of vane grooves which are disposed in a radiation direction in an outer circumferential portion of the rotor;

a cam ring that is arranged to surround the rotor and the plurality of vanes;

a side plate that covers the cam ring and includes a suction port which is configured to supply a working fluid to the cam ring and is formed on an outer circumference of the side plate as a portion being recessed to a radially inner side of the rotation shaft to form the supply unit; and

wherein the suction port has an inner end portion, which extends along and is spaced from an inner circumference of the cam ring by a constant distance in a radial direction of the rotation shaft.

2. The vane pump according to claim **1**, further comprising:

another side plate that is arranged on a side opposite to the side plate across the cam ring to cover the cam ring and includes another suction port which is configured to supply the working fluid to the cam ring and is formed on an outer circumference of the other side plate as a portion being recessed to the radially inner side of the rotation shaft, and

wherein the other suction port has another inner end portion, which extends along and is spaced from the inner circumference of the cam ring by another constant distance in a radial direction of the rotation shaft.

3. The vane pump according to claim **2**, wherein

the side plate includes a through-hole, on the radially inner side of the rotation shaft compared to the other suction portion, which supplies the working fluid pressing the plurality of vanes to allow the plurality of vanes to protrude from the rotor into the cam ring, and

the through-hole is formed in such a manner that an outer end portion thereof extends and is spaced from the inner circumference of the cam ring by another constant distance in the radial direction.

4. The vane pump according to claim **1**, wherein

the side plate includes a through-hole, on the radially inner side of the rotation shaft compared to the suction portion, which supplies the working fluid pressing the plurality of vanes to allow the plurality of vanes to protrude from the rotor into the cam ring, and

the through-hole is formed in such a manner that an outer end portion thereof extends and is spaced from the inner circumference of the cam ring by a constant distance in the radial direction.

5. The vane pump according to claim **1**, wherein the inner end portion of the suction portion has an arc shape, which is smaller in radius than an outer circumferential circle of the side plate.

6. The vane pump according to claim **5**, wherein the arc shape of the inner end portion is a part of an elliptical shape.

7. The vane pump according to claim **1**, wherein

an opening with the constant distance in the radial direction is formed between the inner end portion and the inner circumference of the cam ring.

8. The vane pump according to claim **7**, wherein in the opening, the vane is configured to protrude by the constant distance to a radially outer side of the rotation shaft when the vane is in operation.

9. The vane pump according to claim **1**, wherein a position of the inner end portion is determined such that the vane protrudes from the inner side plate by less than half of the length thereof in the radial direction.

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